Hydrogen Refueling Technology

Michele R. Davies (Primary Contact), Robert Heffley
HyRadix, Inc.
175 W. Oakton
Des Plaines, IL 60018
Phone: (847) 375-7094; Fax: (847) 391-2596; E-mail: Michele.Davies@HyRadix.com

DOE Technology Development Manager: Lucito Cataquiz
Phone: (202) 586-0729; Fax: (202) 586-9811; E-mail: Lucito.Cataquiz@ee.doe.gov

Subcontractor: SunLine Services, Thousand Palms, CA

Objectives

- Demonstrate hydrogen fueling station
- Develop and demonstrate on-site autothermal reforming (ATR) of natural gas
- Analyze hydrogen cost vs. target of $5/kg in 2003
- Evaluate fuel cell vehicle refueling under real-world conditions
- Support public education on hydrogen and fuel cells

Technical Barriers

This project addresses the following technical barriers from the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year R,D&D Plan:

Hydrogen Production

- A. Fuel Processor Capital Costs
- B. Operation and Maintenance
- E. Control and Safety

Technology Validation

- C. Hydrogen Refueling Infrastructure
- D. Maintenance and Training Facilities

Education

- B. Lack of Demonstrations or Examples of Real World Use

Approach

- Fabrication and testing of prototype (50 Nm^3/hr) natural gas reformer with pressure swing adsorption (PSA)
- Design and fabrication of demonstration (100 Nm^3/hr) natural gas reformer with PSA
- Installation and commissioning of demonstration unit
- Process design of compression, storage & dispensing (CS&D) system
- CS&D equipment design and selection
- CS&D installation and permitting

- Training of system operator
- Demonstration of integrated system
- Data acquisition, analysis and reporting
- Continuing public education on hydrogen and fuel cells at SunLine

Accomplishments

- Built and tested prototype reformer, including PSA system
- Completed design and began fabrication of demonstration reformer, including PSA system
- Designed, selected, and purchased CS&D equipment
- Obtained permitting required for demonstration at SunLine

Future Directions

- Complete fabrication of demonstration unit
- Deliver and install demonstration unit at SunLine
- Commission demonstration unit
- Install & commission CS&D equipment
- Demonstrate and evaluate integrated hydrogen refueling station

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Introduction

The objective of this project is to develop and demonstrate a hydrogen refueling station that combines HyRadix's on-site hydrogen generation technology with compression, storage and dispensing facilities designed by SunLine Services Group. The refueling station will be located at the SunLine facility in Thousand Palms, California, and will provide low cost hydrogen to fuel three fuel cell buses and several fuel cell cars and street sweepers. The refueling station will also provide hydrogen that will be blended with compressed natural gas (CNG) to form a hydrogen-compressed natural gas (HCNG) blend and used in SunLine's fleet of converted CNG buses.

HyRadix's hydrogen generation technology is based on ATR of natural gas combined with a PSA unit to purify the hydrogen. HyRadix's reformer will produce 100 Nm^3/hr of high purity (99.95%+) hydrogen. SunLine is drawing on their unique experience of being one of the few experienced operators of fuel cell vehicles to design and build a compression, storage and dispensing system to be integrated with the HyRadix reformer. The hydrogen will be compressed and stored at a pressure of 6250 psi to allow for dispensing at 5000 psi. The target refueling rates are 15 minutes per bus and 3-5 minutes per car. SunLine will also continue their directive to educate the public on hydrogen as an energy carrier and fuel cells.

Approach

The HyRadix hydrogen generation technology is based on autothermal reforming at a small scale, producing a reformate stream of 40-50% hydrogen. This gas stream is then purified to 99.95+% through a purpose-designed small-scale pressure swing adsorption unit. HyRadix built and tested a prototype 50-Nm^3/hr unit – half the output of the final demonstration unit – in order to incorporate improvements into the final design of the 100-Nm^3/hr demonstration unit. Autothermal reforming combines partial oxidation and steam reforming, making efficient use of heat, but does not require exotic metallurgy.

The SC&D system designed by SunLine will compress the hydrogen to 6250 psi, store it at that pressure and then dispense to the vehicles at a maximum of 5000 psi. The compression system comprises two-stage diaphragm compressors, which maximize energy efficiency, reduce manufacturing costs and increase flexibility while maintaining contamination-free hydrogen. The two-stage design permits startup under the high inlet pressure of the gas stream coming from the PSA. The storage component consists of high-pressure carbon fiber wrapped cylinders rated at a maximum pressure of 7250 psi. The dispenser system is a two-hose dispenser capable of dispensing at 3600 psi on one side and at 5000 psi on the other side for HCNG and fuel cell vehicles, respectively. The entire dispensing system will be rated for 7250 psi for safety reasons.

HyRadix will develop operations and maintenance manuals for the demonstration unit and provide on-site training to SunLine personnel. SunLine staff will be responsible for the operation of the unit during the demonstration phase.

Results

The most important result of the project to date has been the learning from the operation and testing of the prototype unit, which has resulted in improved design for the unit that will be placed in service at SunLine. Several burner designs and control schemes were tried. This helped give us a robust burner design. Operation of the prototype has also brought to attention the importance of reducing thermal mass for both the start-up time and for process efficiency. The unit was tested at several different flow rates. This is important to determine if any anomalies exist that may limit the range of performance. In addition, the unit was started and stopped many times. This provides confidence that the unit can be run safely and with repeatable results. Smooth start-up has been achieved in less time than is required for conventional steam reforming plants. In addition, extensive logic testing has taken place. These tests helped create the software that will run the 100-Nm^3/hr hydrogen unit.

The operation of the prototype (see Figure 1) has confirmed that it produces both reformate and high-purity hydrogen consistent with the project targets. Stream qualities were monitored, and these results helped prove that the unit removes the sulfur in the natural gas stream, has a stack-gas very low in NO_x and SO_x, and provides product hydrogen at target purity with almost undetectable levels of CO. The PSA unit was tuned to give optimum hydrogen purity. This tuning will help set the standard for all future units.

The 100-Nm^3/hr demonstration plant that will be installed at SunLine is in the final stages of fabrication, incorporating the learning from the prototype plant. (See Figure 2.) The unit is mechanically complete.

- All structural components are fabricated.
- All equipment is installed on the structure.
- All piping is installed between equipment.

Figure 1. Prototype Unit Operating at HyRadix

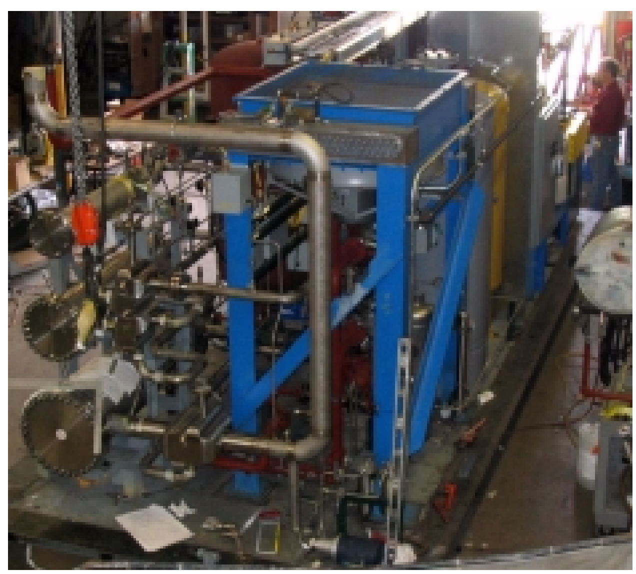

Figure 2. Demonstration Unit in Final Stages of Fabrication

- All tubing is installed between equipment.
- All tie-in connections are complete and ready for connection on site.
- All instrumentation is installed and wired.
- All power and control wiring is complete.

The enclosure is complete and painted.

- The enclosure protects the equipment from the elements.
- The enclosure is partially installed for shipping protection.
- The enclosure panels will be installed on site.

Testing is under way.

- All hydrostatic testing is complete.
- Leak testing is 50% complete.
- Instrument and electrical check-out is 35% complete.

Conclusions

- Operation and testing of the prototype unit has resulted in improved design for the demonstration unit.

- The prototype unit produces hydrogen consistent with targets and with very low emissions and CO.

FY 2003 Publications/Presentations

1. Davies, M., D. Cepla, and D. Sioui, "Small Scale On-site Hydrogen Generation for Refueling Applications from Multiple Feedstocks," National Hydrogen Association Conference, March 2003, Washington D.C